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Current, 3.65 vebers. Resistance in circuit, about 10 ohms. Resistance of light, 3.3 ohms. With a speed of 1,325, total resistance 9 ohms, and current 5.71 vebers, a light varying from 600 to 900 candle-powers was obtained. With a speed of 1,280, resistance 7 ohms, and current 5.20 vebers, the light varied from 650 to 900 candle-powers. Doubtless a much greater light could be obtained with a different regulator and means of obtaining a high speed.

The effects of the current were very fine, and have been frequently described in connection with the Wilde, Gramme, and other machines. Thick wires were melted, heavy weights sustained in the air in the interior of large coils, and excellent diamagnetic effects shown. The induced current on breaking the circuit was very severe when taken through the body, and the spark very long and bright.

The advantages of this machine are its simplicity, compactness, and small weight, compared with other machines of equal power; and little or no trouble was experienced from heating with the currents here employed. In conclusion, we wish to express our hearty thanks to Mr. Farmer for lending us the machine, and hope that we may be enabled to continue these experiments with this and other machines next year, if we can secure an adequate motor and proper means of measuring power.

VII. — ANSWER TO M. JAMIN'S OBJECTIONS TO AMPÈRE'S THEORY.

By William W. Jacques.

It is the purpose of this paper to answer some objections which M. Jamin has made to Ampère's theory of magnetism.

In the Comptes Rendus for Jan. 12, 1874, M. Jamin published the results of some experiments, in which he obtained the laws of the distribution of magnetism in a soft iron bar which formed the core of two coils by measuring the force necessary to detach an armature when placed at different points along the bar. He gives the equations to the curves obtained by sending an electric current through one of the coils, through both coils in the same direction, and through both coils in opposite directions; and finds that the force necessary to detach the armature at any given point is less when the currents are parallel than when opposed; from which he draws essentially the following conclusions: —

1°. If we admit the theory of solenoids, the action of parallel currents ought to be added, and the amount of magnetic intensity to be increased. The reverse takes place.

2°. When the currents of the coils are sent in opposite directions, they ought to act inversely on the particular currents of the iron, and the results should diminish each other. On the contrary, they are added.

3°. The action of the bobbins should, in this case, be nothing at the middle point of the bar. It is not so. We cannot say that there is, at this point, a resultant pole, for it would manifest itself by a point of repulsion.

M. Jamin then states that these results seem to him to require a modification in the theory of solenoids.

Mr. D. Sears has (American Journal, July, 1874) measured the distribution of magnetism in an iron bar which formed the armature of the cores of two coils, by sliding a coil of fine wire, whose terminals were connected with a galvanometer, along this armature, and measuring the instantaneous current induced in this secondary coil when the armature was magnetized by sending a current through the primary coils. His results are opposed to those of Jamin. The case, however, is not exactly that of Jamin, and I have therefore, after repeating Mr. Sears's experiments with similar results, applied this method of measuring the distribution of magnetism, by means of a coil of fine wire, to Jamin's apparatus, as follows: —

I made a bar of soft iron, 50 cm. long, the core of two coils, as in Jamin's experiment, and so connected the coils with a battery that a current could be sent through a single coil, or through both coils in the same or in opposite directions. One of Farmer's thermo-batteries was used as a source of electricity, because of the very great constancy of its current. A small coil of fine wire, like that used by Mr. Sears, was arranged to slide along the bar, and its terminals were connected with a Thomson's galvanometer. When a current was sent through the primary coils, magnetism was induced in the bar, and this, in its turn, induced an instantaneous current in the coil of fine wire, and so caused a deflection of the galvanometer. Although the secondary coil was parallel to the primaries, I found, by substituting a glass rod for the iron bar, that the direct action of the inducing coils on the secondary coil was exceedingly small, excepting when these were brought very near together, which it was not necessary to do in this experiment.

The method used in these experiments is more delicate than Jamin's, as may be shown by constructing curves from the observations in Table I., or by the smallness of the differences in the last column of that table;

and, since we know the positions of the poles of a magnet relatively to a surrounding coil, we may determine the kind of magnetism, or, in other words, the direction of the Amperian currents in either half of the bar, which Jamin's method fails to do.

The results of this experiment, which are directly opposed to those of Jamin, and, therefore, tend to confirm the theory of Ampère, are given in the following table: —

TABLE I.

$X=$	Currents Parallel.	Currents Opposed.	Calculated Mean.	Single Bobbin.	Differences.
15	55	46	50.5	50.0	+ .5
18	33	24	28.5	30.0	—1.5
20	26	16	21.0	21.0	.0
21	23	12	17.5		
22	21	9	15.0		
23	20	6	13.0	13.0	.0
24	19	3	11.0		
25	19	0	9.5	8.5	+1.0
26	19	— 3	8.0		
27	20	— 6	7.0	6.5	+ .5
28	21	— 9	6.0		
29	23	—12	5.5		
30	26	—16	5.0	4.5	+ .5
32	33	—24	6.5		
35	55	—45	5.0	3.0	+2.0

The first column gives the distances from the left end of the bar; column two gives the deflections of the galvanometer for parallel currents; column three for opposed currents; column four the calculated means of columns two and three; column five the deflections due to a single bobbin; and column six the differences between columns four and five.

The equation to the curve of column six is $y = \frac{A}{B^x} = \frac{470}{1.17^x}$, which is the same as the equation obtained by Jamin for the same case.

From the above table it may be seen that, when currents are parallel, the deflection of the galvanometer is greater than when they are opposed; and, when the current is sent through a single bobbin, the deflections are very nearly the means of the other two, as should be the case if Ampère's theory were true.

The conclusions which I have drawn are: —

1°. Parallel currents add to each other.

2°. Opposed currents diminish each other.

3°. The action in the latter case ought to be nothing at the middle of the bar. Experiment shows this to be the case.

Having thus shown the different results of these two methods, I purpose now to show that Jamin's results, instead of requiring a modification of Ampère's theory, are a direct consequence of that theory.

Let us, in approaching this subject, first see what would be the condition of the Ampèrian currents in a bar placed at right angles across the core of an electro-magnet. Suppose the electro-magnet to be placed vertically, and the bar horizontally on top of it. Suppose further that the current passes, in the part of the inducing coil nearest the observer, from right to left. Then, since the Ampèrian currents, in the core of the magnet, would tend, at the angles made by the core and the cross-bar, to induce currents in the cross-bar parallel to those in the core, we should have the Ampèrian currents, in the face of the bar towards the observer, flowing from below upwards in the part of the bar to the right of the core, and from above downwards in the other half; *i.e.*, a current in one direction about the core induces currents in opposite directions in the two halves of the cross-bar.

I have proved this experimentally by placing the coil of fine wire connected with the galvanometer, before spoken of as the secondary coil, at different points on this cross-bar. When the coil was placed to the right of the inducing coil, the deflection of the galvanometer was in one direction; when the coil was placed on the other side, the deflection was in the opposite direction: showing that, in the two halves of the cross-bar, opposite Ampèrian currents do actually exist. That this effect was not due to the direct action of the principal coil on the secondary, was shown by substituting a glass rod for the cross-bar. Let us now, keeping the two bars in the same relative position, make the cross-bar the core of two coils, and let the bar which we have just used as a core represent the armature used in Jamin's experiments. When opposite currents are sent through the primary coils, opposite Ampèrian currents will be induced in the two halves of the bar; and, as the converse of the preceding experiment, parallel currents will be induced in the armature, and these, strengthening each other, will increase the attraction between the bar and the armature. If, on the contrary, parallel currents be sent through the coils, parallel Ampèrian currents will be induced in the bar, and opposite currents in the armature; and, if the armature be placed at the middle of the bar, these currents should neutralize each other and the attraction ought to be nothing.

To prove these conditions of the Ampèrian currents experimentally, I have fixed the secondary coil on the armature at some considerable distance from the bar, and so investigated the conditions of the currents in the armature, when currents were sent through the primary coils in the same and in opposite directions, with the following results. The armature being placed at the middle of the bar, and parallel currents being sent through the primary coils, there was no deflection of the galvanometer. When opposite currents were sent through the primary coils, the deflection was about 60 mm. A current through a single coil gave a deflection of 32 mm., or very nearly the mean of the other two. A very slight correction was made, due to the direct action of the primary on the secondary coil.

These experiments then gave the same results as those at which we had arrived theoretically, showing most conclusively that this is the correct explanation of Jamin's results.

As a further proof of the illegitimacy of Jamin's conclusions, and a proof which is independent of the secondary coil and galvanometer previously used, I have, using Jamin's apparatus, with the single modification of making the armature quite long in proportion to its diameter, and approaching it to the bar always in such a position that its longer axis shall be parallel to the axis of the bar, succeeded in obtaining results directly opposed to those of Jamin, and in harmony with the result of my previous experiments.

In order to make the experiment plain, let us see what ought to be the condition of the Ampèrian currents in such an armature.

Since it is quite long in proportion to its diameter, the Ampèrian currents would tend to arrange themselves at right angles to its axis; and, approaching the armature in the manner described, the currents in the armature would be parallel to those in the bar. With such an armature, therefore, we ought to have a greater attraction when the currents through the primary coils are parallel than when opposed.

That this is the case I have proved by the following experiment: A small armature of chemically pure iron was made, with a length of 6.5 mm. and diameter of only .8 mm. This was approached, with its axis parallel to the bar, always to the middle of the bar, since it is at this point that the difference in effect of parallel and opposed currents ought to be most marked.

The actual strength of the magnetism of the bar at this point could be varied by moving the inducing coils to or from the middle point, and in this way the intensity was made such that when parallel currents were sent through the coils the armature was supported by the bar. Upon reversing the current in one of the coils and again approaching the armature, the attraction of the bar was insufficient to support it in this position, although it would assume a position at right angles to the bar, when, as should be the case, it was supported. These results show, as we had expected, that parallel currents increase each other, while opposite currents diminish each other.

The experiment was repeated, approaching the armature with its axis at right angles to the axis of the bar, when results similar to those of Jamin were obtained.

The delicacy of these experiments required a great number of repetitions. This was done, and care was also taken to carefully clean the armature each time lest any moisture from the hands, or other foreign matter, should make it adhere to the bar. Chemically pure iron was used to prevent the armatures acquiring a permanent magnetism.

I have thus attempted to show that the results of M. Jamin's experiments, although undoubtedly correct, do not warrant the conclusions respecting Ampère's theory which he has drawn, but, on the contrary, are a direct consequence of that theory: first, by investigating the condition of the currents in the armature; and, secondly, by showing that contrary results are obtained by making the armature very long in proportion to its diameter, and approaching it always with its longer axis parallel to that of the bar.